Utility Distribution Planning 101

Michael Coddington, NREL
Kevin Schneider, PNNL

**Distribution Systems and Planning Training
for Western States**

May 2-3, 2018

Context

- ► Distribution planning has traditionally been focused on maintaining:
  - ☐ Safety
  - ☐ Reliability
  - ☐ At reasonable cost
- ► At the core distribution planning <u>supports investment decisions</u>
- ► As the grid and resource mix are changing, distribution systems are changing and distribution planning is changing
  - ☐ In many places, a lot of new gen is connected to the distribution system
  - ☐ Distribution system has least amount of utility visibility/control
- ► In some states, more detailed distribution plans are being required :
  - ☐ Hosting capacity
  - ☐ Locational benefits and non-wires alternatives
- ► New skill sets may be required as well as coordination across entities within the utility

Electric Distribution System Planning – An Overview

Electric Distribution Planning is a key utility strategy/function that is used to forecast changes on the grid and modify the system accordingly, all with a focus on;

Safety

- Design and maintain an electric system that does not place the general public nor utility workers at risk

Reliability

- Provide the power that the consumers need
- Maintain power quality
  - Maintain stable voltage at point of delivery
  - Support a stable frequency
- Reduce number of outages
 - Frequency (SAIFI) and Duration (SAIDI/CAIDI) are tracked

Cost

- Supply power and energy at an fair and acceptable price

Load Forecasting

➢ Track peak loads (using SCADA data)

➢ Publish annual long-range forecast

➢ Evaluate each distribution feeder for annual growth, new loads

➢ Feeder load forecasts aggregate to show substation status, need for expansion

➢ Substations may require upgraded transformers, new transformer banks, transmission, distribution equipment

➢ System Planning (transmission) use this to plan line upgrades (new lines, larger lines, higher voltages)

➢ Substation departments evaluate the need for larger transformers or additional transformer banks


Load Forecast Feeder 1777
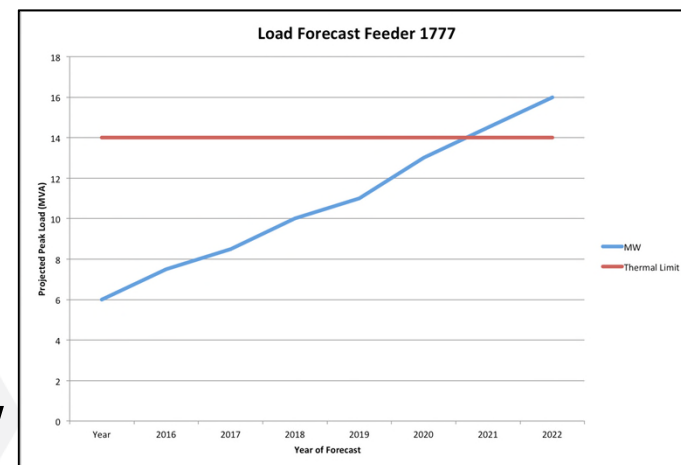
** Larger utilities often have groups of engineers that focus entirely on distribution planning functions

Traditional Areas of Focus for Larger Utilities - Continued

► Reliability (SAIDI, SAIFI)

- ☐ Feeder-Level protection
- ☐ Under Frequency Load Shedding (UFLS) schedules
- ☐ PUC/customer complaint resolution

► Power quality support

► Voltage support (ANSI C84.1)

- ☐ Capacitor placement
- ☐ Voltage regulator placement

► Evaluation of "special projects" such as large DER systems

► Large distribution project design

► These traditional functions remain, while new challenges and opportunities are emerging

Image: NREL Pix 03207

ANSI C84.1 Voltage Standard

2018 | 6
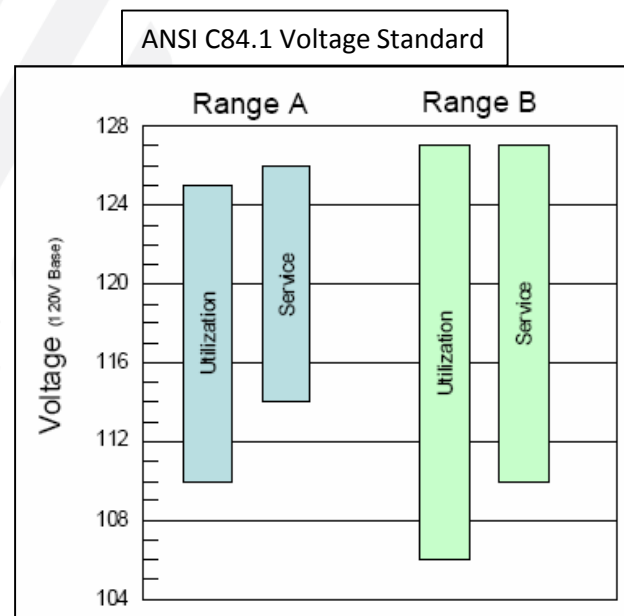
DISTRIBUTION MODELING TOOLS

Question:

How do utility engineers plan their system changes and upgrades?

Answer:

Sophisticated computerized tools are often utilized by utility engineers, but there are many types of tools available.

The Foundation for Computer Models - GIS

► Most utilities have a Geospatial Information System (GIS) in place, where they track their distribution lines, transformers, customers, substations, and sometimes the DER (like PV) systems.

► GIS departments only update GIS systems to track any system changes

► Modeling platform users "Extract" the GIS data and then run the model

► Thus, it is critical to have a high-quality GIS system which is accurate
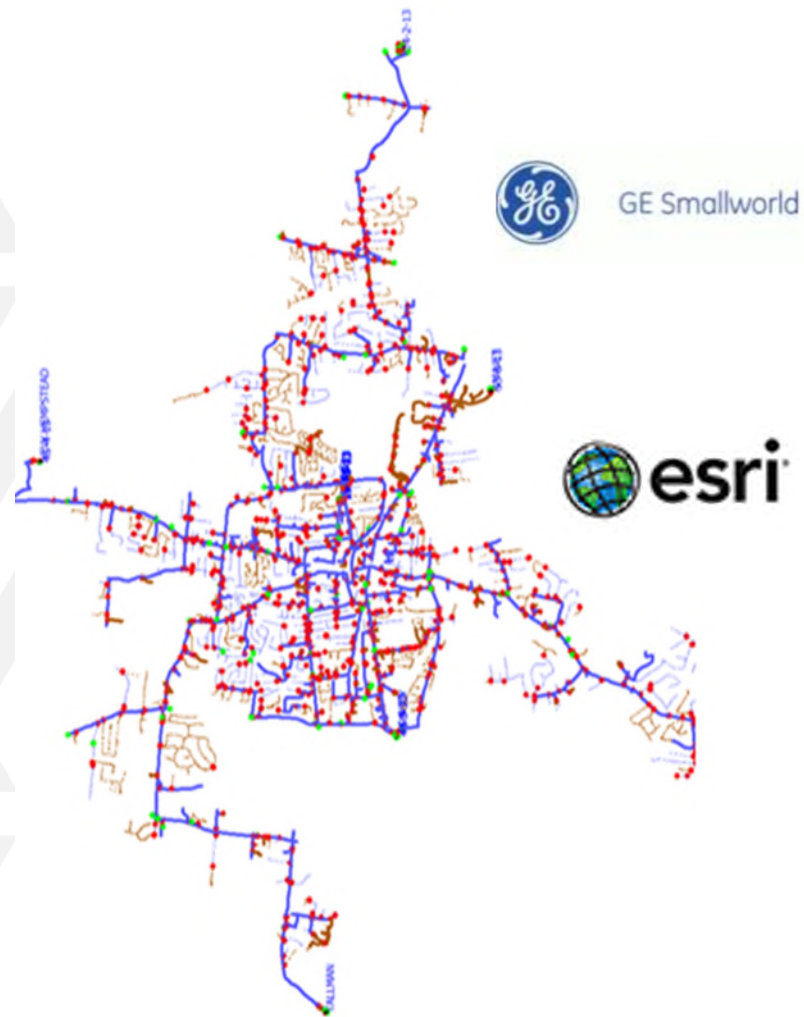
Distribution Modeling Tools - Observations

Larger utilities typically use the following (with exceptions):

- ☐ CYMDIST (power flow)
- ☐ Synergi (power flow)
- ☐ ASPEN (protection)
- ☐ DEW (power flow)
- ☐ Others….

Small-Medium utilities typically use

- ☐ Milsoft Windmil (power flow)
- ☐ Milsoft Light Table (protection)
- ☐ Others….
- ☐ Consultants
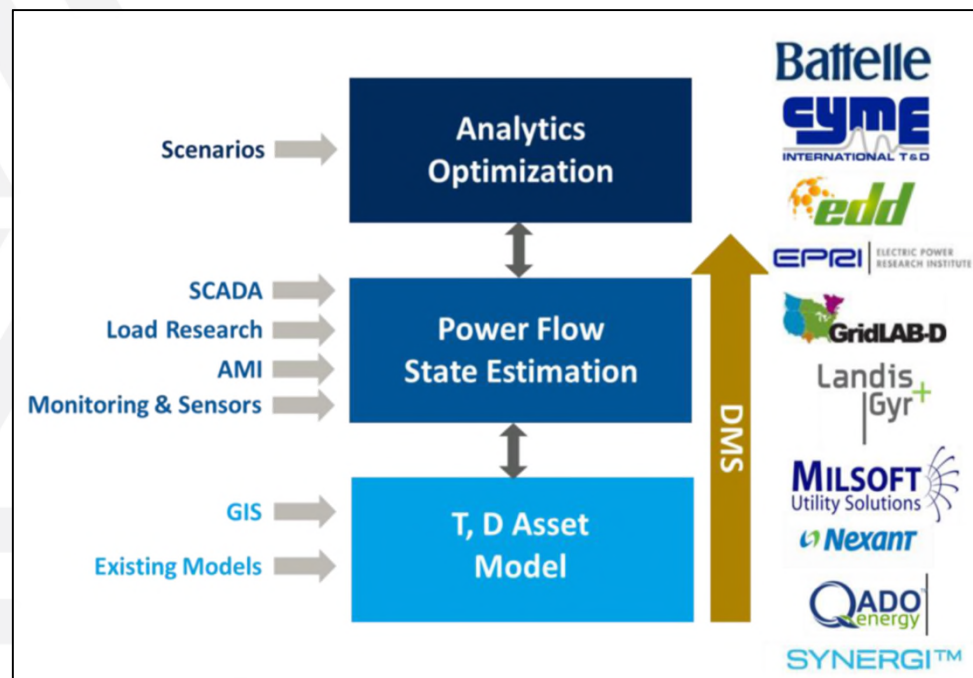
Modeling software is generally a large investment, as is trained staff, thus utilities are quite hesitant to change platforms!

Larger utilities have teams of model experts, while smaller utilities rely on institutional knowledge or third parties
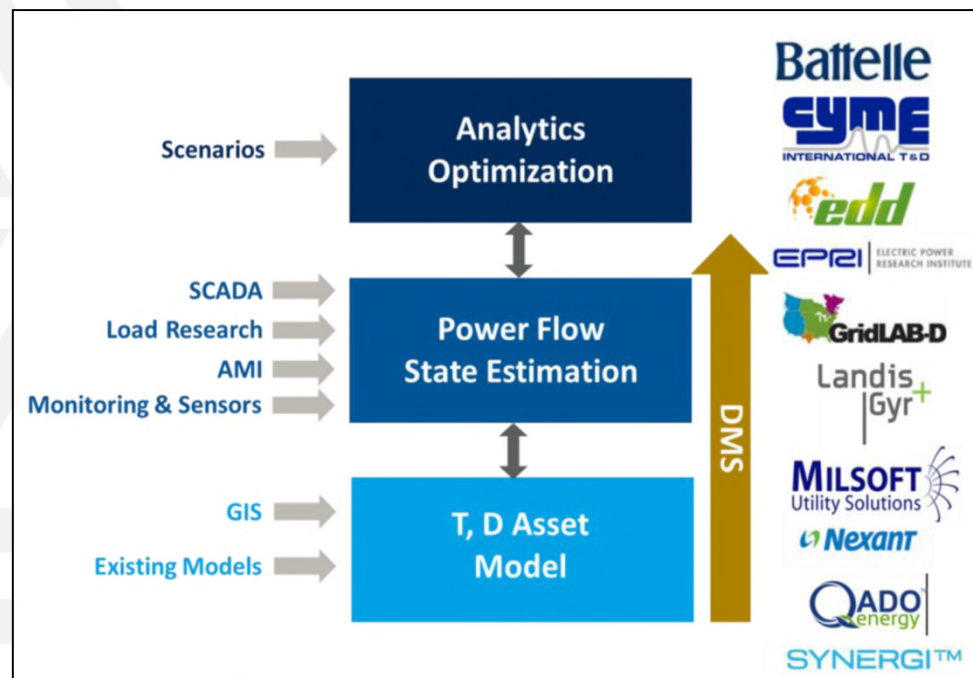
► Typically Used Tools
  ☐ CymDist
  ☐ Milsoft Windmil
  ☐ Synergi
  ☐ ASPEN

► Research Centric Tools
  ☐ OpenDSS
  ☐ GridLab-D

Identify System Risks

► Determine N-0 (system intact overloads) and N-1 (based on one-point of failure) risks based on the peak demand and available capacity

► Other considerations
   ☐ Power Quality (low or high voltage)
   ☐ Reliability (line and equipment exposure)
   ☐ Environmental considerations (e.g. line losses)
   ☐ Safety
   ☐ Legal
   ☐ Financial

Create Risk Mitigation and Projects

► Traditional poles and wires solutions to mitigate system risks

  ☐ New distribution feeders
  ☐ Reconductoring existing feeders
  ☐ New substations
  ☐ Expanding existing substations

Source: NREL Pix 08216

Annual Electric Distribution Budget

Create Annual Capital Budget

► Determine funding by program

► Evaluate Customer Minutes Out and value of service reliability

► Determine Cost Benefit Ratio

► Prioritize projects over a 5 year time

► Budget based on corporate guidelines

Note: This complex planning approach may not be used by small and mid-sized utilities, but is important for larger utilities due to the scale of operations and number of customers

Example Electric Distribution Budget

Program	Percentage
New Service	19.9%
Elec Asset Health	11.2%
Street Lights	2.8%
Elec Capacity	9.6%
Elec Mandates	8.4%
Reliability	16.1%
Sub Capacity	12.4%
Sub Asset Health	5.5%
Equip Purchase	9.7%
Fleet	2.0%
Other	2.4%

New Load Construction Allowance vs. Customer Paid DER Mitigation

► Most IOUs have Construction Allowance (CA) for new projects, sometimes results in zero up-front cost for new construction

   ◻ Investments are recovered through tariff design, as investments are generally placed in the "rate base"

► Distributed Energy Resources (DER) such as PV systems often interconnect without system upgrades, but pay for any upgrades if required to mitigate potential problems

Source: NREL PIX, Coddington

System Expansion Project: Con Edison's BQDM

Deferral of ~$1 billion in traditional network upgrades with distributed solutions

► Meets capacity shortfall via $200 million program
  - Non-traditional customer-sided 41 MW ($150 m)
  - Utility-sided solutions 11 MW ($50 m)
► Long duration, night peaking network requires a portfolio of solution
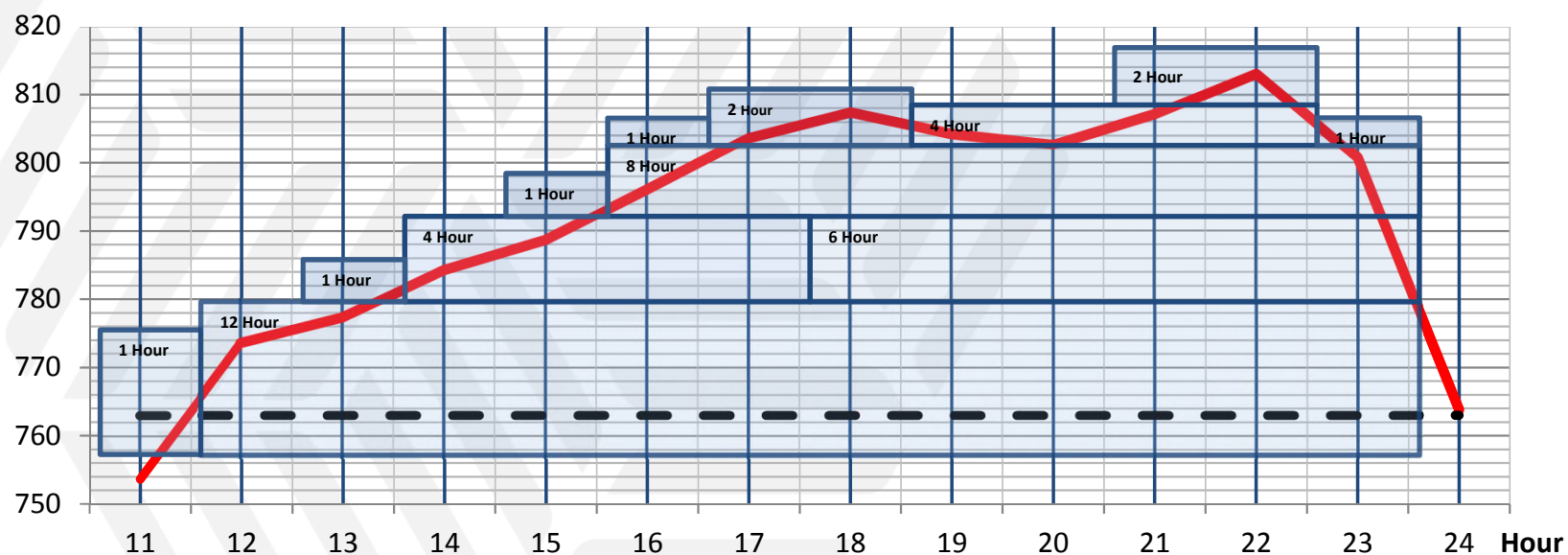► The effective DER contribution can be located anywhere within the foot print

Targeted area (4 networks)
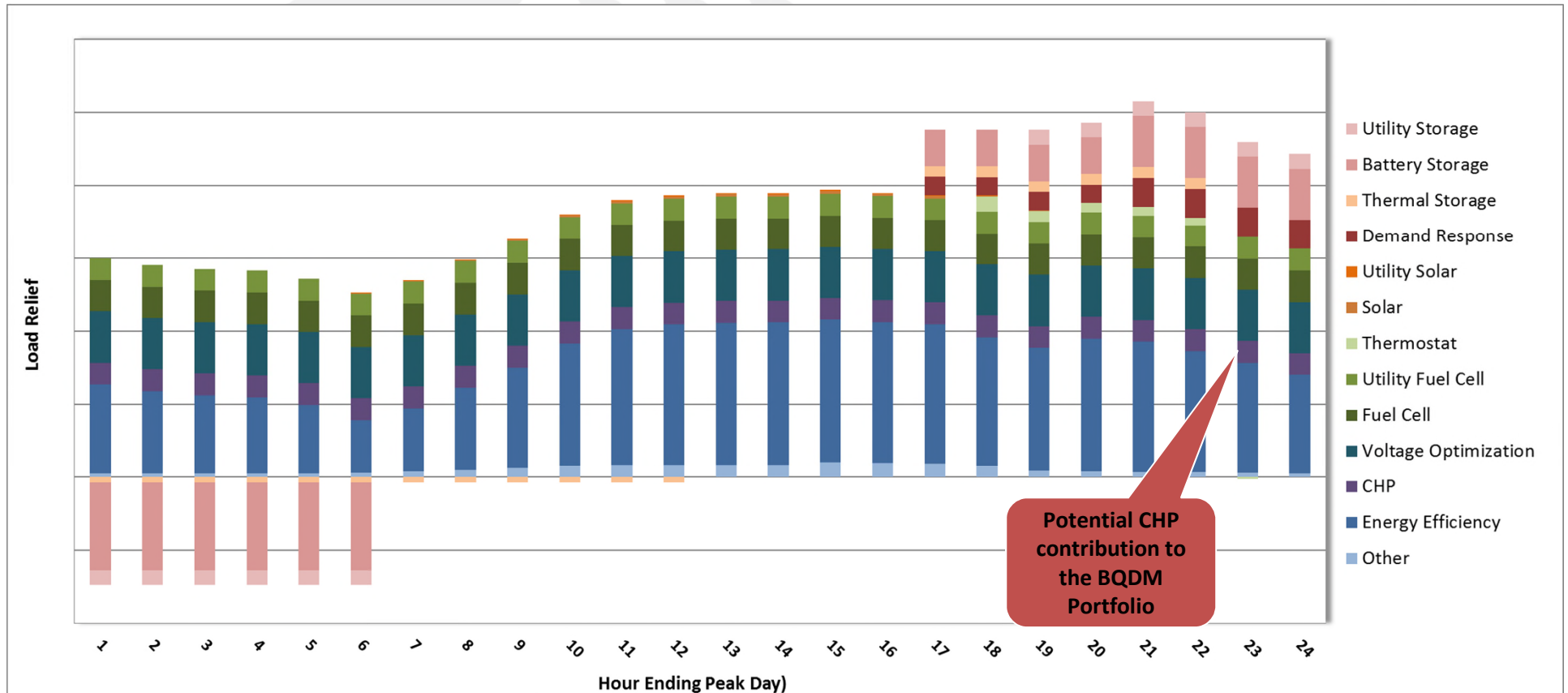
Brooklyn-Queens Demand Management

Description

- $1 billion substation deferral using portfolio of alternative investments in Brownsville network

- Earn rate-of-return plus incentive based on implementation

Example Network Peak Day Load Curve

# Illustrative BQDM Portfolio

BQDM - Battery Storage System

12 MW-hoursof energy in Lithium Iron Phosphate batteries. Remotely controlled or automated unmanned operation. 1) Charge during off-peak, 2) Discharge for peak-shaving, 3) Repeat as needed. (Note the outdoor installation). Graphic – Con Edison

Integrated Distribution Planning
A Means to Plan for DER Integration
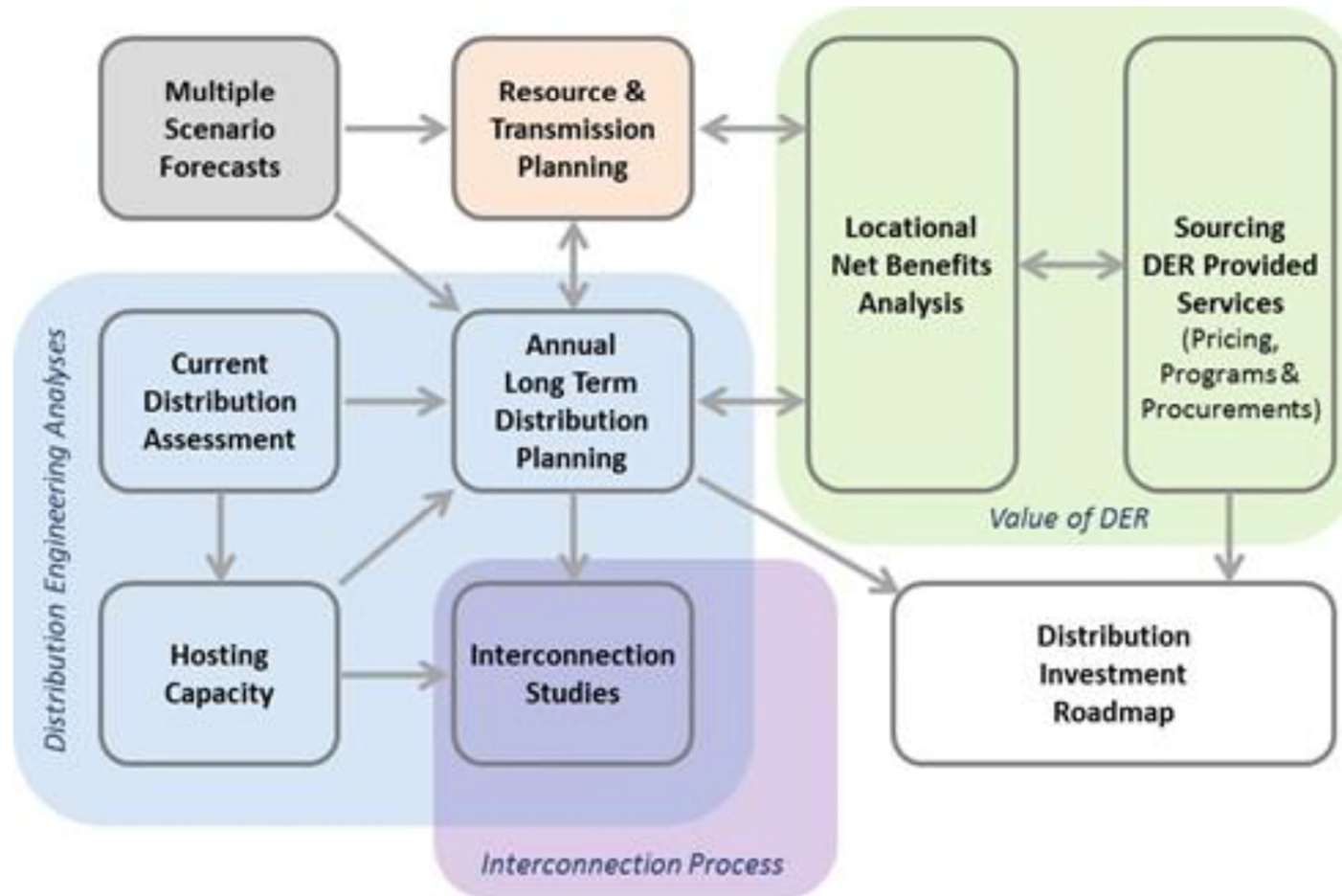
Basic Questions for PUC Staff Related to Utility Distribution Mapping & Modeling

► What GIS platform has the utility invested in?

► How many staff are dedicated to updating or cleaning GIS models?

► How accurate is their system?

► What updates are planned?

  ☐ Adding secondary wires?

  ☐ Adding load points (customers)

  ☐ Adding DERs?

► What is the lag time between construction/changes and GIS updates in the system?

► Are phases identified correctly?

► *Is the GIS system obsolete? What is the cost of replacement?*
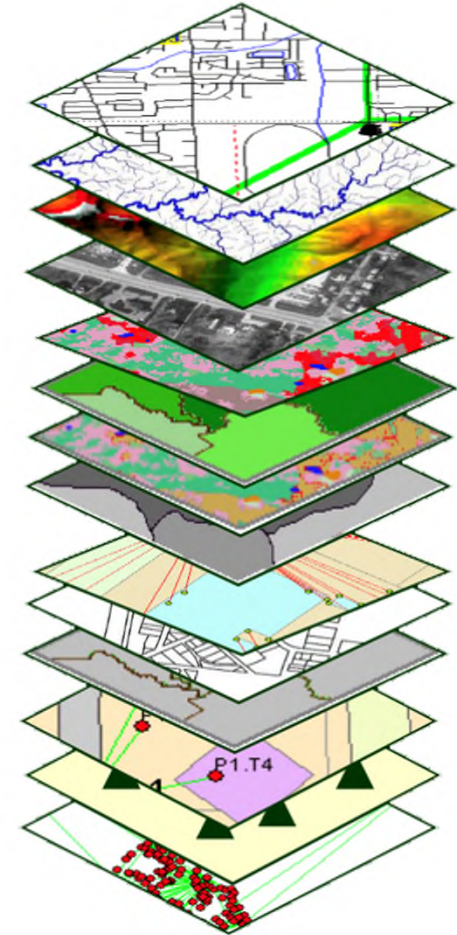
Source: EPRI GIS Interest Group

Basic Questions for PUC Staff Related to Utility Distribution Mapping & Modeling
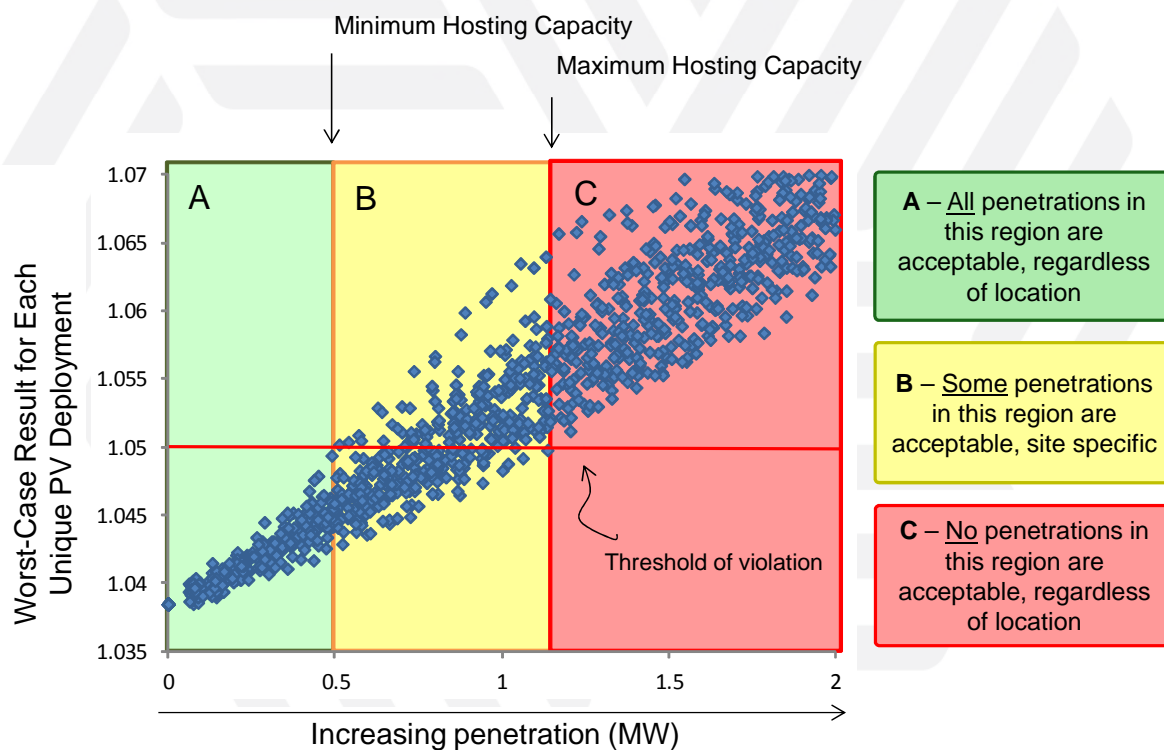
► What power flow modeling platform does the utility use?

► How many staff use this platform?

► What modeling platform is used for protection coordination? (i.e. fuses, circuit breakers)

► How often does the power flow model extract data from GIS?

► Are DERs modeled in power flow?

► Are DERs tracked for combined analysis?

► Is the utility prepared to model advanced inverters?

► Does the utility use any type of "Hosting Capacity" metrics on distribution circuits?

► Are there defined limits of DER hosting capacity based on location, load, voltage or just policy?

Minimum Hosting Capacity

Maximum Hosting Capacity

A – <u>All</u> penetrations in this region are acceptable, regardless of location

B – <u>Some</u> penetrations in this region are acceptable, site specific

C – <u>No</u> penetrations in this region are acceptable, regardless of location

Y-axis: Worst-Case Result for Each Unique PV Deployment

X-axis values: 1.035, 1.04, 1.045, 1.05, 1.055, 1.06, 1.065, 1.07 / 0, 0.5, 1, 1.5, 2

Threshold of violation

Increasing penetration (MW)

Source: EPRI

Other Distribution Modeling Questions

► Does the utility pursue a Volt-VAr Optimization (VVO) strategy?

  ☐ If so, how do they use power flow models to assist them?

  ☐ Does a VVO strategy impact the operation of other devices such as capacitors, voltage regulators, or substation load tap changers (LTCs)? If so, do the models allow that to be simulated?
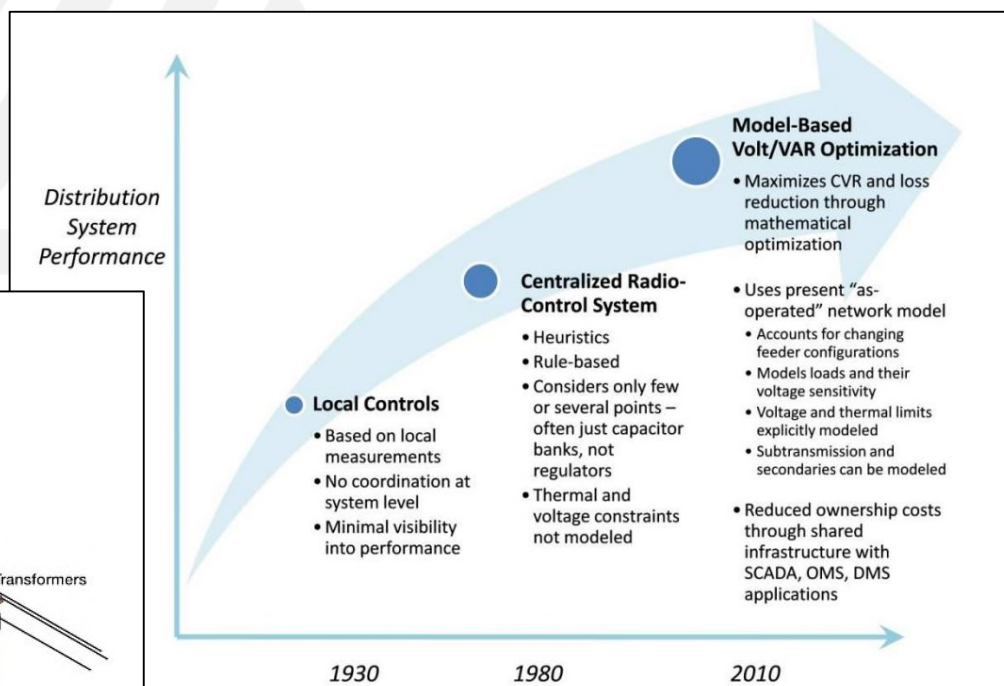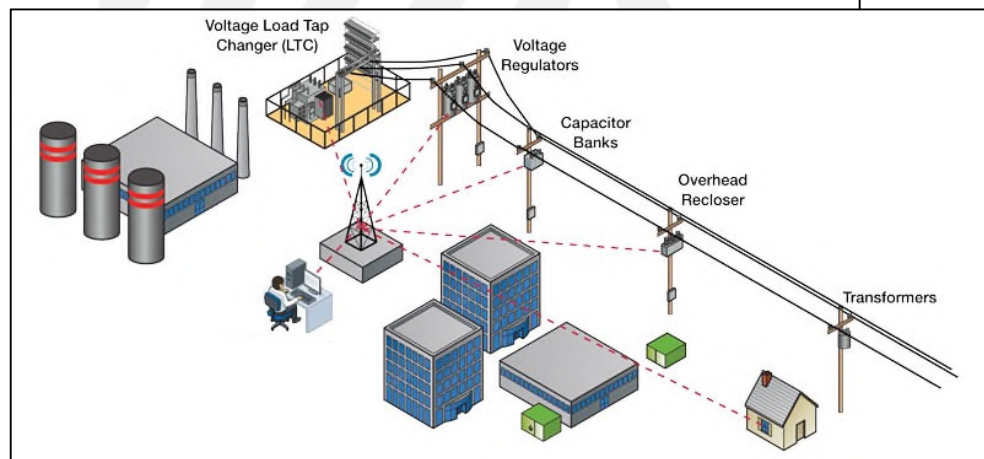
Source: NEMA "The Value of Volt/VAr Technologies"

Kevin Schneider

Classes of Distribution Planning Tools

- ► Forecasting
  - ☐ DER forecasting
  - ☐ Load forecasting
- ► Power flow analysis
  - ☐ Peak Capacity Power Flow Study
  - ☐ Voltage drop study
  - ☐ Ampacity study
  - ☐ Contingency and restoration study
  - ☐ Reliability study
  - ☐ Load profile study
  - ☐ Stochastic power flow study
  - ☐ Volt/Var study
  - ☐ Real-time performance study
  - ☐ Time series power flow analysis

- ► Power quality analysis
  - ☐ Voltage sag and swell study
  - ☐ Harmonics study
- ► Fault analysis
  - ☐ Arc flash hazard study
  - ☐ Protection coordination study
  - ☐ Fault location identification study
- ► Dynamic analysis
  - ☐ Long-term dynamics study
  - ☐ Electromechanical dynamics study
  - ☐ Electromagnetic transients study
- ► Advanced optimization

Load forecasting tools

► **Inputs to load forecasting tools**
  - Weather, geographic, economic, demographic, DER and demand response data

► **Forecasting DER growth requires**
  - DER type, quantity, location, timing and other attributes

► **Factors that that impact DER forecasting:**
  - Historical adoption rates
  - Economic return for the customer
  - Available DER incentives
  - Procurement programs

► **Output of load forecasting tools:**
  - Load profiles across circuits, banks and subsections of the circuit
  - Necessary temporal and spatial granularity to considering impacts

► **Inputs for DER forecasting:**
  - Market information (e.g., fuel prices, existing electricity tariff)
  - Customer load information (hourly end use loads), and
  - DER technology information (e.g. capital costs, operating and maintenance costs, performance data
  - Other customer decision factors

Advances in Electric Distribution System Planning (example PV analysis)

► Traditional planning studies have focused on:
  ☐ Capacity planning
  ☐ Cost
  ☐ Safety

► Because of the newer technologies that are being deployed at the distribution level, the planning process must change. Capacity is not the only factor to consider.

► As an example, the future deployment of small scale residential solar cannot be predicted, the planning process must take into account this uncertainty.

► 15 prototypical circuits were used to examine the larger parent population of SCE circuits.

► The following is an example process that was developed of Southern California Edison as part of California Solar Initiative #4.
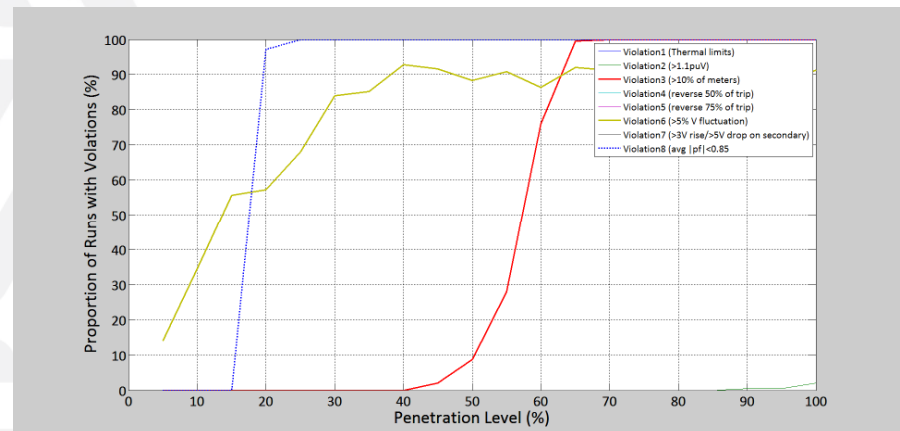
Determining Native PV Limits of a Circuit

► Step 1-Define key metrics: What is, and what is not an operational limit that would prevent the deployment of additional solar. (utility dependent)

► Step 2-Clear base case models of violations: Time-series models of representative circuits were developed and the base condition must be free of violations.

► Step 3- Deploy Monte-Carlo PV adoption models: A socio-economic PV adoption model provides different "likely" future scenarios for each circuit.

► Step 4- Run simulations on various scenarios to determine the native PV limit for the circuit. In this case, 50 simulations were conducted at each penetration level.

| Violation #	Violation	Violation Description
	Table 4.1 - Circuit Operational Limits and Thresholds For determining Native Limits	
1	Thermal Overloads	Limit: Exceeding any device thermal limit, 100% rating (200% for secondary service transformers)
2	High Instant Voltage	Limit: Any instantaneous voltage over 1.10 p.u. at any point in the system.
3	5 min ANSI Violation	Limit: ANSI C84.1: 0.95>V>1.05 p.u. for 5 minutes at >10% of meters in the system.
4	Moderate Reverse Power	Warning: Any reverse power that exceeds 50% of the minimum trip setting of the substation breaker or a recloser. (Requires analysis of protection coordination)
5	High Reverse Power	Limit: Any reverse power that exceeds 75% of the minimum trip setting of the substation breaker or a recloser.
6	Voltage Flicker	Limit: any voltage change at a PV point of common coupling that is greater than 5% between two one-minute simulation time-steps. (Adapted from the Voltage fluctuation design limits, May 1994)
7	Voltage Drop/Rise on Secondary	Limit: 3V drop or 5V rise across the secondary distribution system (Defined as the high side of the service transformer to the customer meter)
8	Low Average PF	Warning: Average circuit power factor <0.85 (Measured at substation)
9	Circuit Plan Loading Limit	Warning: Nameplate solar exceeds 10MVA for a 12 kV circuit, 13 MVA for a 16 kV circuit, or 32 MVA for a 33 kV circuit.
10	High Short Circuit Contribution	Warning: Total short circuit contribution from downstream generation not to exceed 87.5% of substation circuit breaker rating

Determining Native PV Limits of a Circuit (Hosting Capacity Determination)

► For each circuit, 4,000 time-series simulations are conducted.

- At each penetration level there are 50 simulations conducted
- Penetration levels at 5% are examined
- Each simulation is a different adoption scenario of solar

► The results of these simulations are distilled into a single plot for each circuit. Example shown at the right.

► The plot can then be used to determine the native limit, and to identify what the limiting factor are.

► The plot forms a basis to determine how to support higher penetration levels of PV, and which technologies might enable this.

Determining Native PV Limits of a Circuit (Mitigation for PV Limits)

► Each of the native limits can be avoided through circuit upgrades.

► Traditional methods:
- ☐ Adjustment of existing voltage regulators
- ☐ Installation of voltage regulators
- ☐ Adjustment of existing capacitors
- ☐ Reconductoring secondary segment
- ☐ Reconductoring primary segment

► Advanced technologies
- ☐ Fixed pf PV inverters
- ☐ Advanced inverter control (CES Rule 21)
- ☐ Centralized battery storage
- ☐ Behind the meter battery storage

► The simulation provide the basis for selecting the best mitigating technologies, but there are many
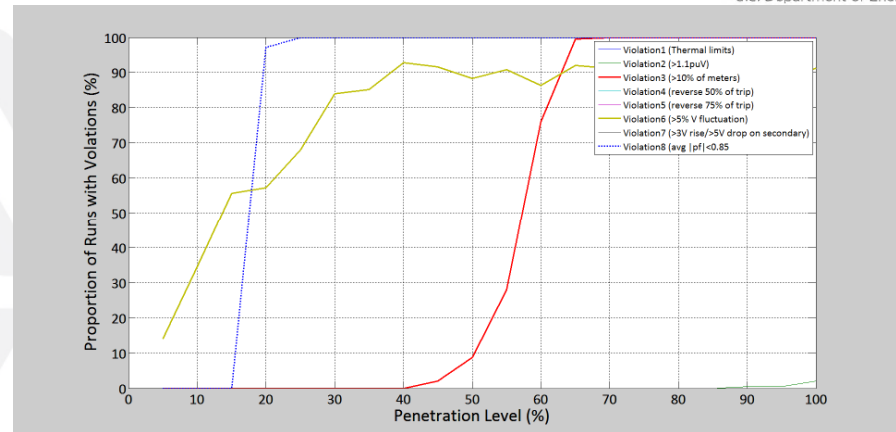
	Table 5.1 - Summary of Mitigation Types and Strategies		
	Traditional Upgrade Strategies		**Non-Traditional Mitigation Strategies**
T1	Adjustment of existing shunt capacitor set points	NT1	Fixed power factor on solar inverters
T2	Removal of existing shunt capacitors	NT2	Advanced Controls on PV Inverters
T3	Addition of shunt capacitors	NT3	Centratlized Energy Storage (utiltity)
T4	Installation of voltage regulators (regulating their output voltage magnitude)	NT4	Commercial Behind Meter Energy Storage
T5	Reconductoring of a primary line/cable segment		
T6	Reconductoring of a secondary line/cable segment		
T7	Upgrade of secondary service transformer		

Determining Native PV Limits of a Circuit (Key Lessons Learned)

► Most SCE circuits could support 100% penetration of PV once the proper mitigation strategies have been applied.

► Nearly 50% of SCE circuits can host less than 50% PV, where approx. 40% can host less than 25% PV

► Determining how to achieve 100% penetration on legacy circuits can be challenging, with a mitigation leading to new violations. (domino effect)

► The most common violations experienced were power factor and voltage based.

► Proper sizing of secondary drops when new solar is installed is essential.

Summary of practices at advanced utilities

► Performing detailed load and DER forecasts, by location

► Conducting hosting capacity studies for some or all feeders and making information publicly available via online maps

► Systematically considering non-wires alternatives (NWA) to traditional distribution system investments – developing NWA suitability criteria

► Investing in automation, communication and information technology improvements to provide greater visibility and flexibility and enable greater levels of DERs

► Looking at value components of DERs by location and incorporating into tariffs. Value components include:*
  - Energy
  - Capacity
  - Environmental
  - Demand reduction and system relief

* From New York REV Value Stack tariff

Discussion and questions

Thank You for Coming!